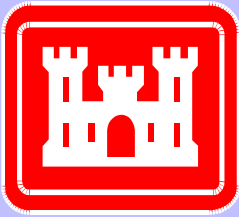


**U.S. Army Corps
of Engineers**

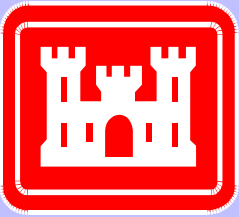
Risk & Reliability Informed Decision Making for US Army Corps of Engineers Infrastructure

**Presentation for the
Asset Management Workshop
16 August 2006**



**U.S. Army Corps
of Engineers**

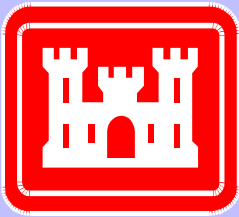
Information on these slides contains some sensitive information from a infrastructure security standpoint and should not be released beyond the intended audience or made public.



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Topics

- **Program Background**
- **Risk Concepts**
- **Business Model**
- **Technical Model**
 - Risk Analysis
 - Data Reduction and Evaluation
- **Results**
 - Flood Damage Reduction
 - Navigation
- **Discussion**

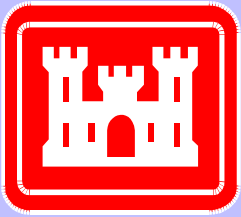


U.S. Army Corps
of Engineers

Vision & Strategy

- **Dam Safety Program aligns with US Army Corps of Engineers Corporate Strategy and Campaign Plan**
 - Ready, Relevant, Reliable, & Responsive
 - **Centrally Managed, Decentrally Executed**
 - **Incorporates Concepts of Risk & Reliability**
 - **Life Cycle Infrastructure/Asset Management**
 - Supports Communities of Practice Concepts
- **“...strong dam safety program in compliance with Federal Guidelines for Dam Safety...”**

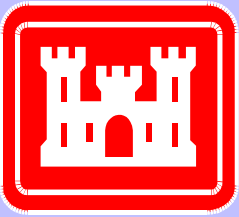
ER1110-2-1156



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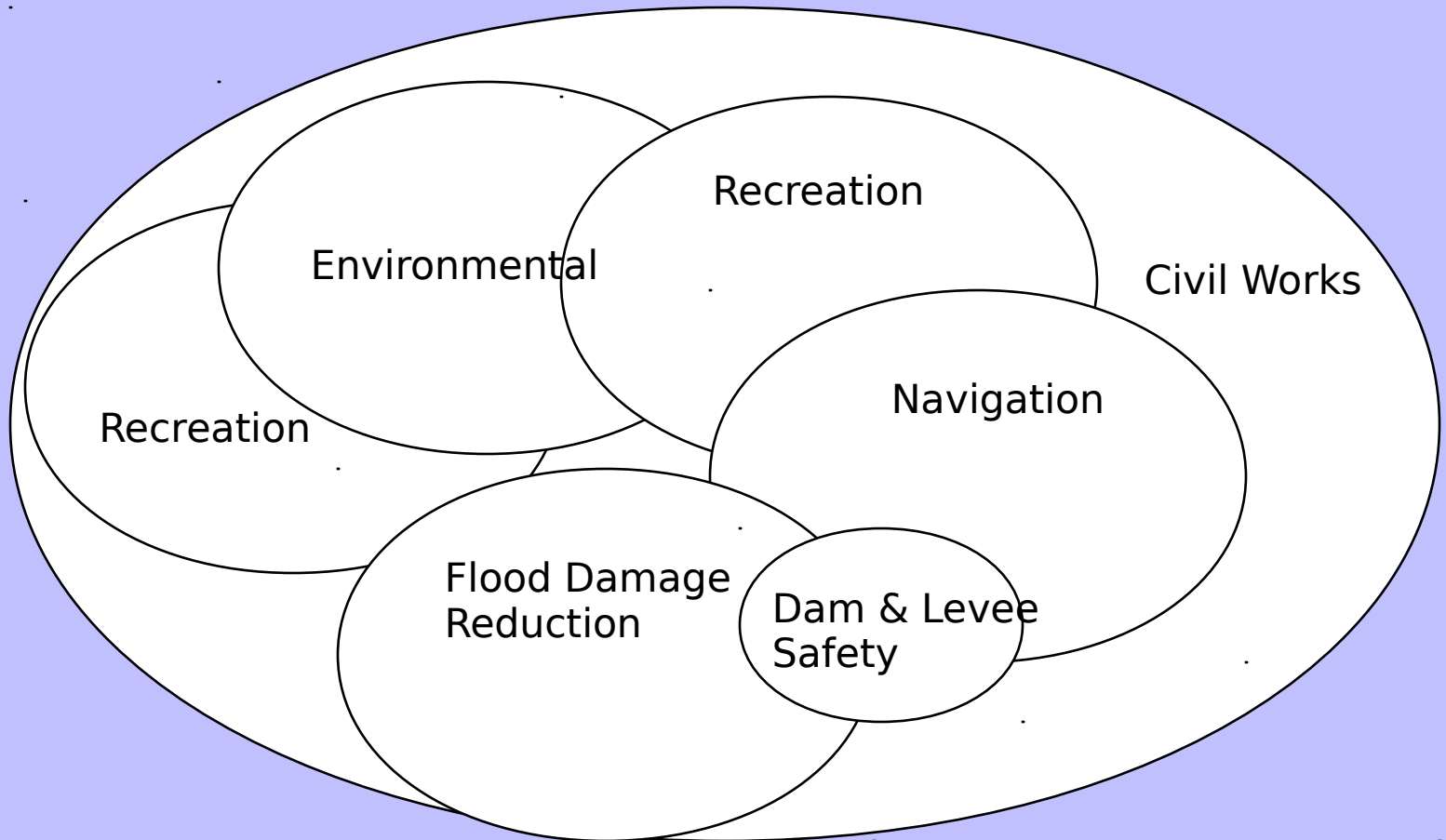
Dam Safety, Defined

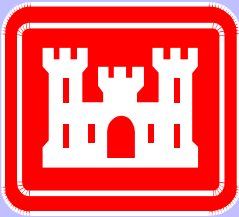
- **“...is the art and science of ensuring the integrity and viability of dams such that they do not present unacceptable risks to the public, property, and the environment.”**
 - ER 1110-201156, Safety of Dams - Policy and Procedure



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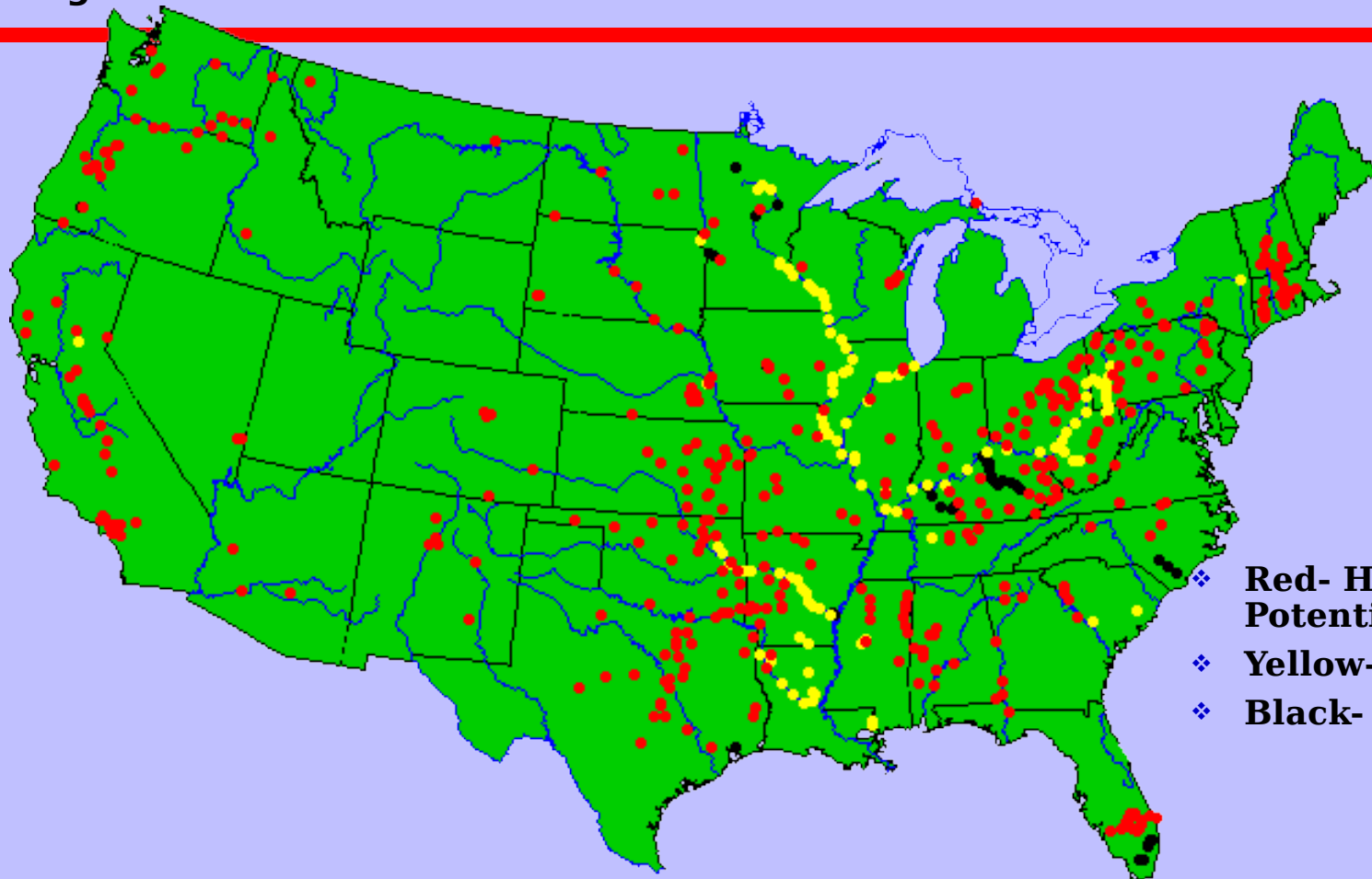
Context





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Location of Corps Dams



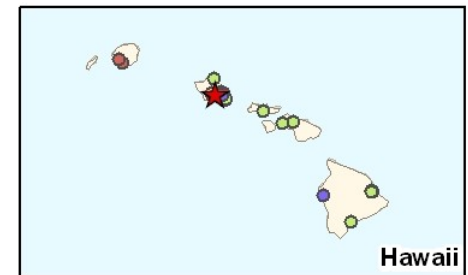
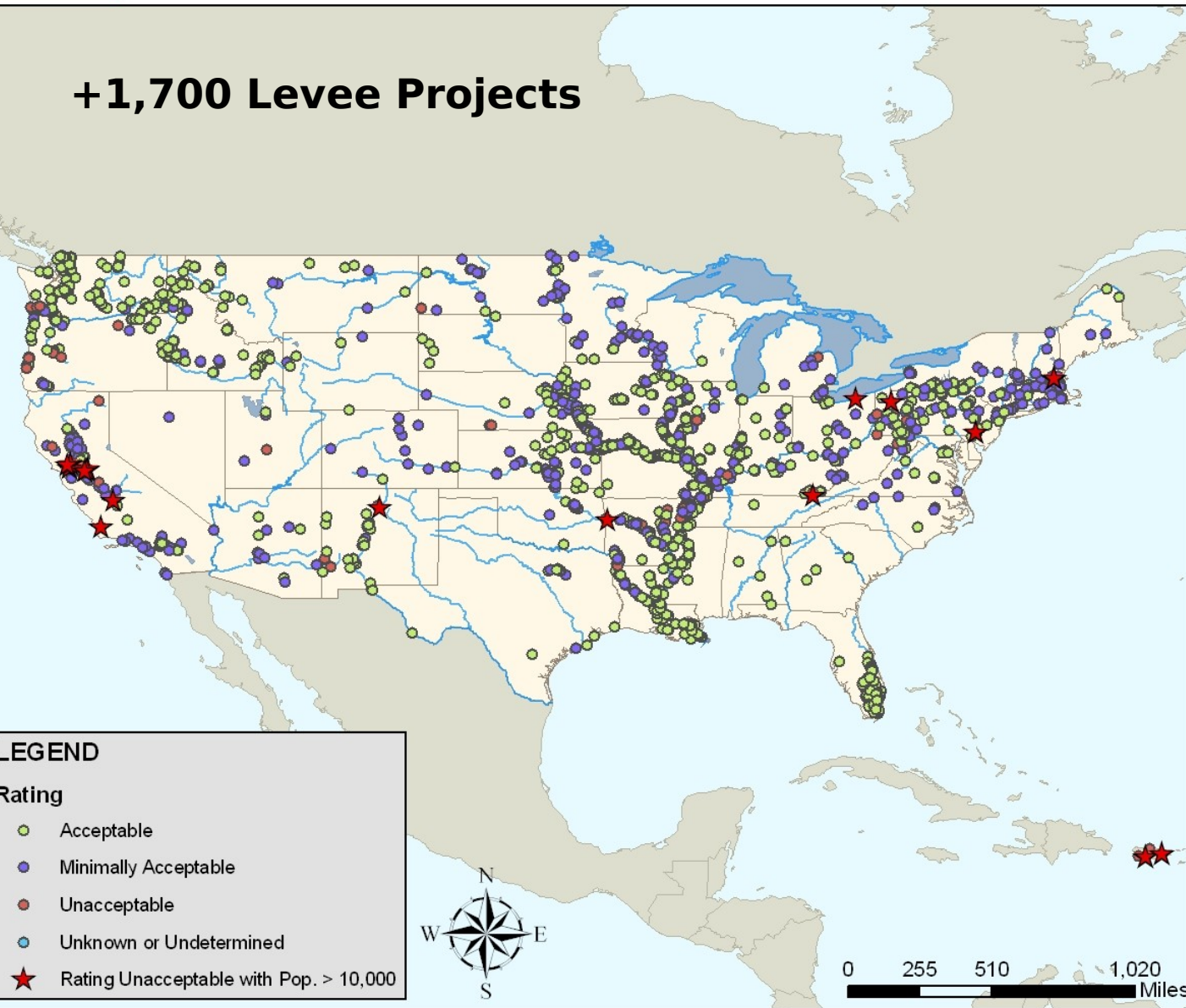
- ❖ Red- High Hazard Potential
- ❖ Yellow- Significant
- ❖ Black- Low

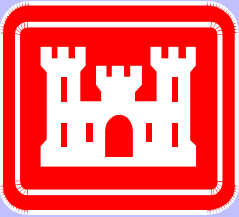


National Levee Database



+1,700 Levee Projects

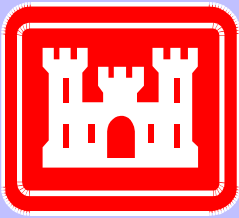




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Portfolio Characteristics

- **Thousands of Separate Flood Damage Reduction Structures**
 - >600 Dam Projects ~ 1000 structures**
 - >1700 Levee Projects**
- **Majority are Earthen**
- **Many are “untested” - flood control purpose**
- **Average age is ~50 years**

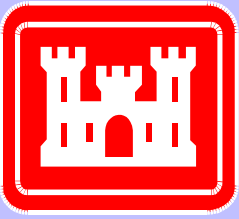


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Dam Safety Program

- **Routine Activities Within the Base Increment of the Budget**
 - Inspections
 - Instrumentation
 - Emergency Action Plans
 - Training
 - Exercises
- **Policy and Criteria**

- **Activities Centrally Prioritized Using Risk**
 - Studies and Investigations
 - Remedial Fixes
 - DSA Program
 - Major Rehab Program
 - Non-Structural Risk Reduction Measures

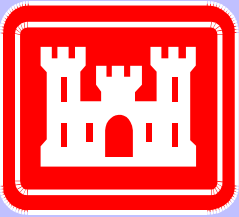


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Risk



- **What's wrong?**
- **How likely is it to occur?**
- **What are the consequences?**



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Definitions

- **Risk = Probability X Consequence**

Loading Event Probability

Loss of Life

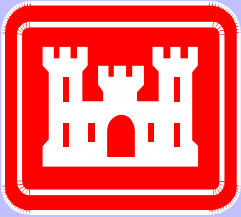
Potential Failure Mode

Economic Damage

Probability of Failure

Other Consequences

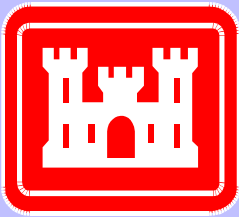
Release Severity Probability



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Why Risk & Reliability?

- **Situational Awareness of Risks**
- **Safer Dams, More Quickly**
- **Better Business Decisions**
- **Expectations**
 - Public and Congressional
 - Profession & Industry
 - Societal and Legal
 - Aligns with Corporate USACE



U.S. Army Corps
of Engineers

Phased Implementation

Phase 1

Screening for Portfolio Risk Assessment (SPRA)

- Focus on “Worst First”
- 3 Cadres Deployed
- FY05: 10% Portfolio
- FY06: Additional 10%
- Yields Relative Ranking

Phase 2

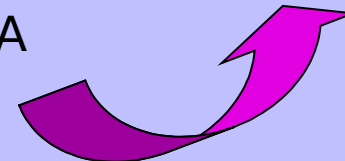
Portfolio Risk Assessment (PRA)

- Development FY06/FY07
- FY07: Beta Test
- Yields Explicit Risks
- Feeds Site Specific RA

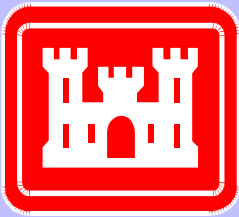
Phase 3

Site Specific Risk Assessment

- To be developed FY08
- Optimizes Remedial Alternative based on risk
- Cost Effectiveness



Business Area	Business Model		
	Historical	Current	Future
Reservoir	Local		DR A
Dams			
Navigation			
Dams	DCR	DRR	DRR
	Increasingly Disciplined & Risk Based		
Levees			
	Defenses	Development	DRR
Security			RAM-CAP?



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Current Organization

Dam Safety Leadership

Don Basham, Dam Safety Officer
Eric Halpin, Special Assistant for Dam Safety
Charles Pearre, Dam Safety Program Manager

Dam Safety Steering
Committee and Dam
Safety CoP

Senior Oversight Group
For
Risk & Reliability

MSC and District
DSOs/DSPMs
Andy Harkness, Lead

Policy & Procedures
Team
Bruce Murray, Lead

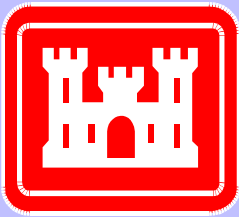
Methodology Team
Dave Schaaf,
Lead

Program
Management Team

Risk Cadre
Jeff McClenathan, Lead

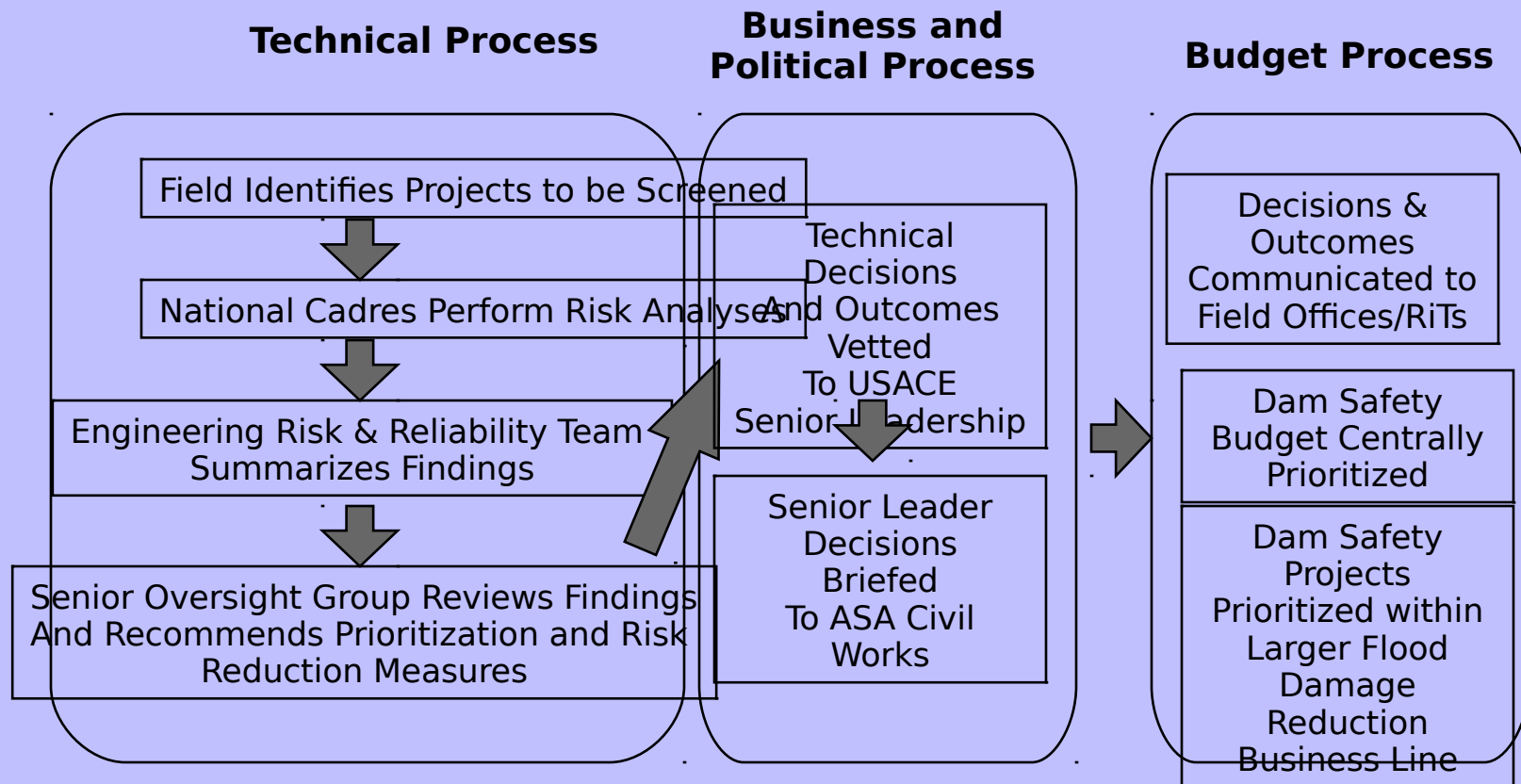
Risk Cadre
Mark Vance, Lead

Risk Cadre
Dennis Seibel, Lead

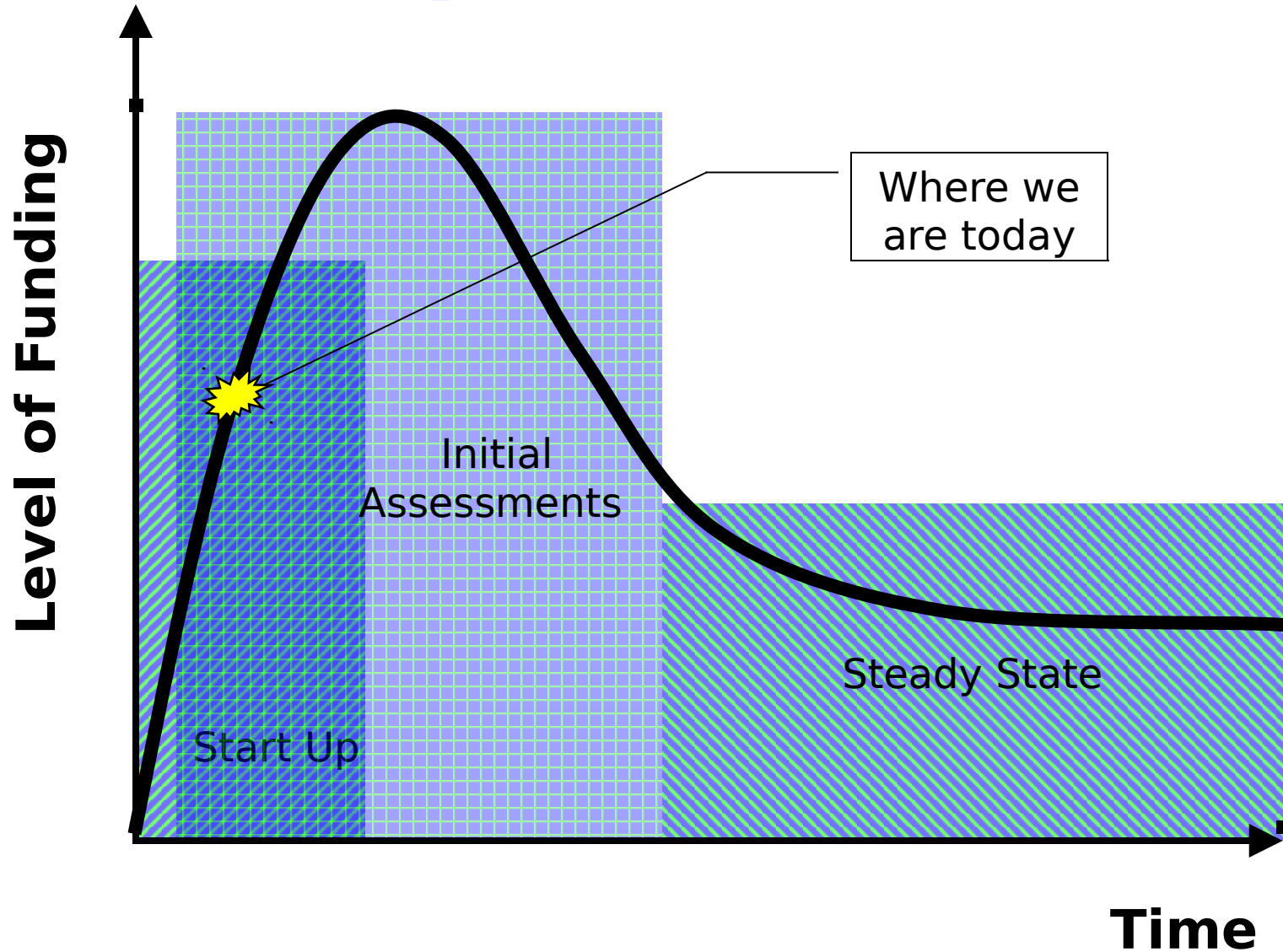


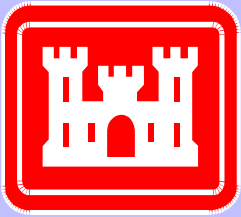
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Decision Process



Implementation

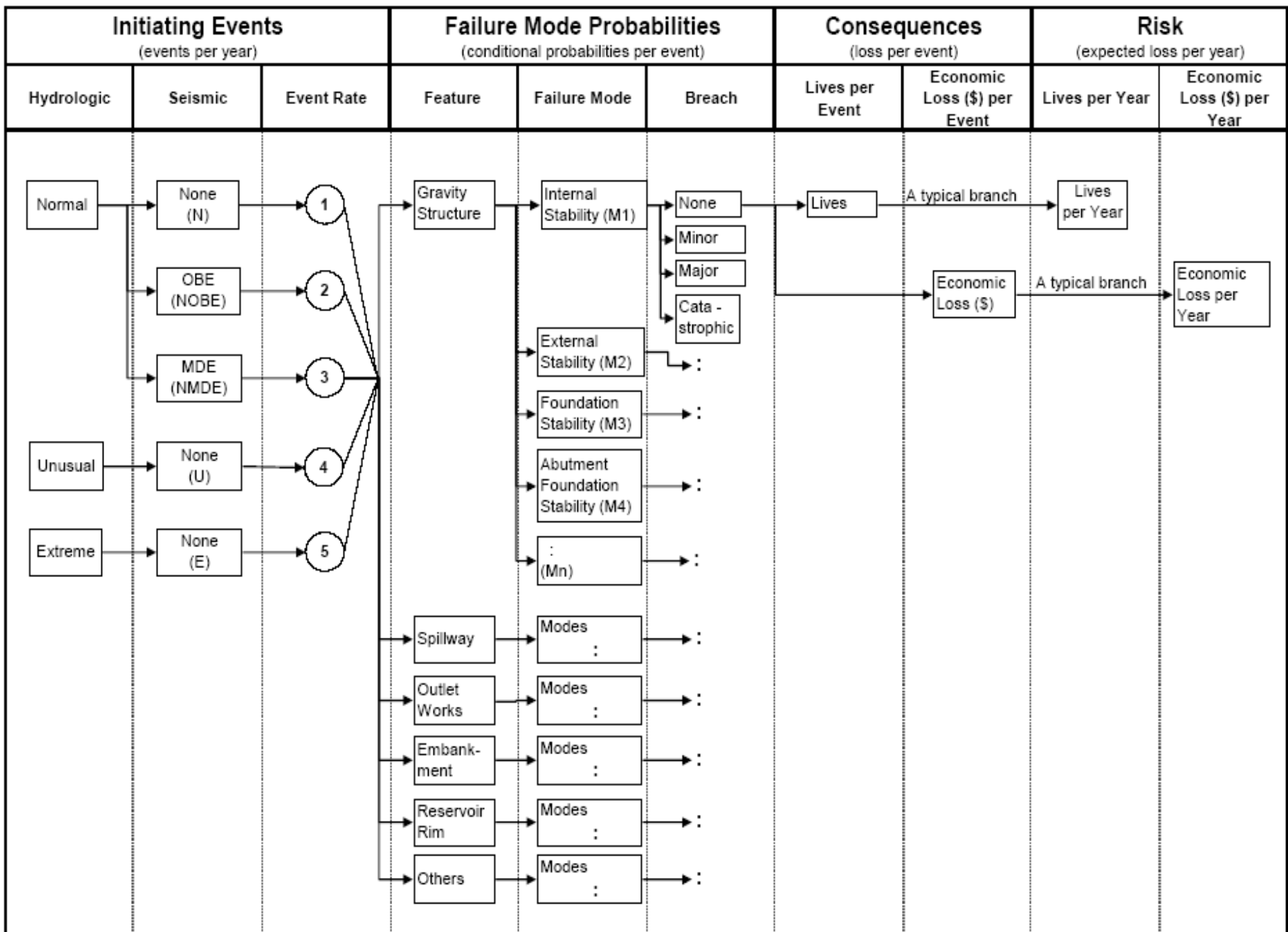


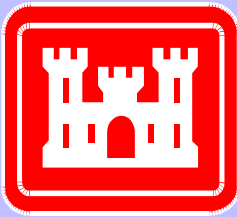


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SPRA Risk Methodology

- **Overview of Risk Engine**
- **Component Evaluation**
- **Engineering Ratings**
- **Probability of Failure**
- **Breach Severity**
- **Consequence Modeling**





**U.S. Army Corps
of Engineers**

Project Evaluation of Features

Emergency Closure System

Service Bridge

Crane & Power

Bulkheads

Gates & Gate Structures

Spillway Gate(s) Failure

Spillway Gate Piers

Gates - Electrical and Mechanical -

Lock Gate Failure (Struct./Elect./Mech.)

Embankment

Embankment Seepage & Piping

Embankment Stability and/or Liquefaction

Erosion

Abutments Seepage & Piping

Abutments Stability and/or Liquefaction

Foundation Seepage & Piping

Foundation Stability and/or Liquefaction

Concrete Section and Stilling Basin – Rock Founded

External Stability

Internal Stability

Foundation Stability

Stilling Basin

Foundation Scour

Abutment Foundation Stability

Concrete Section & Stilling Basin- Pile Founded

External Stability

Internal Stability

Foundation Stability – (Incl. pile capacity)¹

Foundation Scour – (Incl. pile loss of support)

Foundation Seepage & Piping (Incl. upstream cutoff)

Foundation Liquefaction

Stilling Basin - Downstream scour

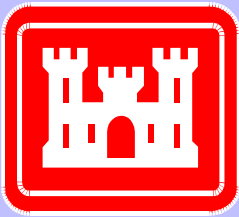
Abutment Foundation Stability

Other Features

Feature 1

Feature 2

Feature 3



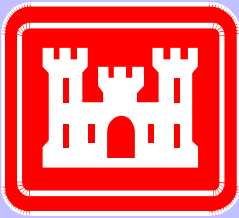
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Feature Failure Mode Performance

- All features rated against a baseline
- Existing Data
- Numerical multipliers applied to baseline failure probabilities to model site conditions

Feature State According to Standards & Criteria	Modifier to New Dam Value	Variable Name
Adequate	1	A
Probably Adequate	10	PA
Probably Inadequate	100	PI
Inadequate	1000	I
Not applicable	0	NA

Engineering Rating Summary					
Feature Low Head Navigation Dam	Normal Water Level	50% Exceedence Duration Water Level with OBE	50% Exceedence Duration Water Level with MDE	Unusual (300yr)	Extreme - (PMF)
Concrete Structures - Rock Foundation					
External Stability	0	0	0	0	0
Internal Stability	0	0	0	0	0
Foundation Stability - under dam	0	0	0	0	0
Scour Protection	0	0	0	0	0
Foundation - Seepage & Piping	0	0	0	0	0
Abutment Foundation Stability	0	0	0	0	0
Concrete Structures - Pile Foundation					
Foundation Seepage & Piping (Incl. unstream cutoff) 1	10	10	10	10	10
Foundation Liquefaction	1	1	1	1	1
External Stability1	1	1	1	1	1
Foundation Stability (Incl. pile capacity) 1	10	10	10	10	10
Internal Stability	1	1	1	1	1
Scour Protection	1000	1000	1000	1000	1000
.....Void.....	0	0	0	0	0
Abutment Foundation Stability1	1	1	1	1	1
Gates & Gate Structure					
Spillway gate(s) failure 2	1000	1000	1000	1000	1000
Spillway gate piers - structural capacity	10	10	10	10	10
Gates - Electrical/Mechanical	1000	1000	1000	1000	1000
Lock gates (struct/elect/mech)	1	1	1	1	1
.....Void.....	0	0	0	0	0
Embankment & Closure Dikes					
Embankment Seepage & Piping	0	0	0	0	0
Embankment Stability and/or Liquefaction	0	0	0	0	0
Erosion: Toe, Surface & Crest	0	0	0	0	0
Abutments Seepage & Piping	0	0	0	0	0
Abutments Stability and/or Liquefaction	0	0	0	0	0
Foundation Seepage & Piping	0	0	0	0	0
Foundation Stability and/or Liquefaction	0	0	0	0	0
Emergency Closure Systems					
Service bridge	10	10	10	10	10
Crane & Power	10	10	10	10	10
Bulkheads	70	1000	1000	1000	1000
.....Void.....	0	0	0	0	0
Other Features					
Feature 1	0	0	0	0	0
Feature 2	0	0	0	0	0
Feature 3	0	0	0	0	0
Feature 4	0	0	0	0	0



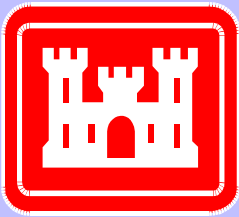
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Failure Mode Probability

Baseline Probabilities

- Evaluation of Major Components and Systems
- Comparisons made to a new structure
- Baseline failure probabilities:
 - ✓ Feature performance Multipliers
 - ✓ Breaching severity
- Design and construction USACE criteria and standards

Feature	Initiating Event				
	Normal	NOBE	NMDE	U	E
Emergency Closure Systems					
Service bridge.	1.0E-05	1.5E-05	2.0E-05	1.0E-05	2.0E-05
Crane & Power	1.0E-05	1.5E-05	2.0E-05	1.0E-05	2.0E-05
Bulkheads	1.0E-04	1.5E-04	2.0E-04	1.0E-04	1.0E-04
Gates & Gate Structure					
Spillway gate(s) failure	1.0E-04	1.5E-04	2.0E-04	1.0E-04	2.0E-04
Spillway gate piers – structural capacity	1.0E-04	1.5E-04	2.0E-04	1.0E-04	2.0E-04
Gates – Electrical/Mechanical	3.0E-04	4.5E-04	6.0E-04	4.5E-04	6.0E-04
Lock gates (struct/elect/mech)	5.0E-04	6.0E-04	7.0E-04	1.0E-05	1.0E-05
Embankment & Closure Dikes					
Embankment Seepage & Piping	3.0E-04	4.0E-04	5.0E-04	3.0E-04	3.0E-04
Embankment Stability and/or Liquefaction	1.0E-04	2.0E-04	4.0E-04	1.0E-04	1.0E-04
Erosion: Toe, Surface & Crest	2.0E-04	2.0E-04	2.0E-04	6.0E-04	9.0E-04
Abutments Seepage & Piping	4.0E-04	4.0E-04	4.0E-04	4.0E-04	4.0E-04
Abutments Stability and/or Liquefaction	2.0E-04	3.0E-04	5.0E-04	2.0E-04	2.0E-04
Foundation Seepage & Piping	5.0E-04	5.0E-04	5.0E-04	5.0E-04	5.0E-04
Foundation Stability and/or Liquefaction	3.0E-04	4.0E-04	6.0E-04	3.0E-04	3.0E-04
Concrete Section & Stilling Basin – Rock Fdn.					
External Stability	1.0E-04	1.5E-04	2.0E-04	1.0E-04	1.0E-04
Internal Stability	1.0E-05	1.5E-05	2.0E-05	1.0E-05	1.0E-05
Foundation Stability – under dam	2.0E-04	3.0E-04	4.0E-04	2.0E-04	2.0E-04
Stilling Basin – scour downstream	1.0E-04	1.5E-04	2.0E-04	1.0E-04	1.0E-04
Foundation Scour – downstream of dam	2.0E-04	3.0E-04	4.0E-04	2.0E-04	2.0E-04
Abutment Foundation Stability	1.0E-04	3.0E-04	4.0E-04	1.0E-04	1.0E-04
Overflow Concrete Section & Stilling Basin – Pile Fdn.					
Foundation Seepage & Piping (Incl. upstream cutoff) ¹	5.0E-04	5.0E-04	5.0E-04	5.0E-04	5.0E-04
Foundation Liquefaction	0	4.0E-04	6.0E-04	0	0
External Stability ¹	1.0E-04	1.5E-04	2.0E-04	1.0E-04	1.0E-04
Foundation Stability (Incl. pile capacity) ¹	2.0E-04	3.0E-04	4.0E-04	2.0E-04	2.0E-04
Internal Stability	1.0E-05	1.5E-05	2.0E-05	1.0E-05	1.0E-05
Foundation Scour (Incl. pile loss of support) ¹	2.0E-04	3.0E-04	4.0E-04	2.0E-04	2.0E-04
Stilling Basin Scour ¹	1.0E-04	1.5E-04	2.0E-04	1.0E-04	1.0E-04
Abutment Foundation Stability ¹	2.0E-04	3.0E-04	5.0E-04	2.0E-04	2.0E-04
Other Features					
Feature 1	0.0	0.0	0.0	0.0	0.0
Feature 2	0.0	0.0	0.0	0.0	0.0
Feature 3	0.0	0.0	0.0	0.0	0.0
Feature 4	0.0	0.0	0.0	0.0	0.0



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Feature Failure Mode Performance Severity of Breaching

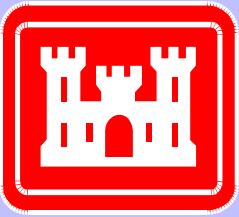
- Level of breaching resulting from feature failure mode performance.
- Adjusted to reflect linked failure modes and site specific conditions.

(a) Concrete Structures

Breach	Probability	Variable Name
None	0.830	Breach1
Minor	0.150	Breach2
Major	0.015	Breach3
Catastrophic	0.005	Breach4

(b) Embankment and Dikes

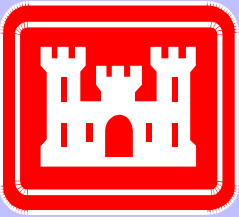
Breach	Probability	Variable Name
None	0.100	Breach5
Minor	0.150	Breach6
Major	0.250	Breach7
Catastrophic	0.500	Breach8



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Consequences

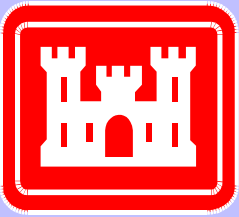
- Project and event specific
- Loss of Life/event
 - ✓ PAR within inundation zone
 - ✓ Fatality rate within PAR
- Economic damage/event
 - ✓ Property damage within inundation zone
 - ✓ Loss of Navigation
 - ✓ Loss of lifelines



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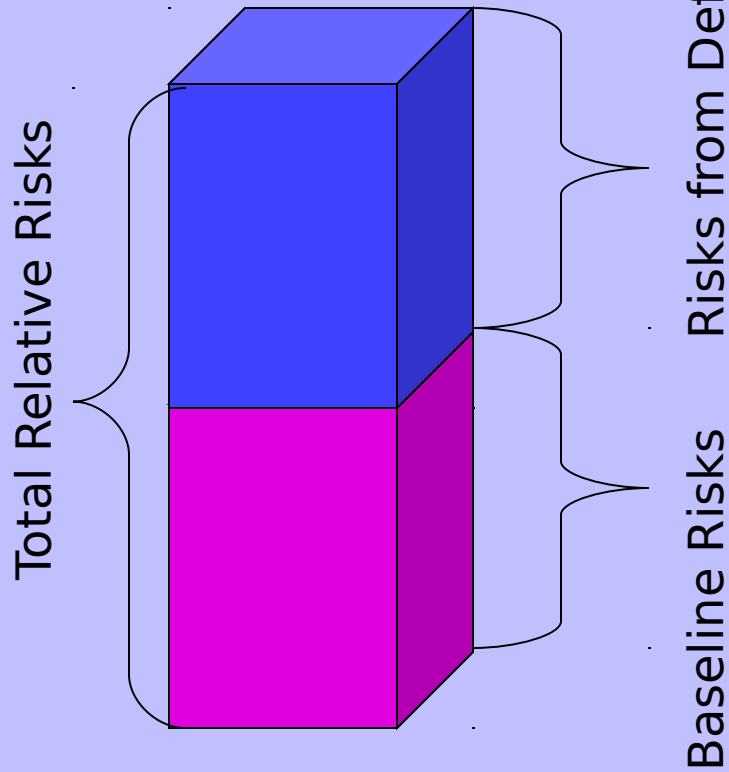
Data Reduction and Evaluation

- **Methods:**
 - **Total Relative Risks**
 - **Life**
 - **Economics**
 - **Analyzed Risks Vice Baseline Risks:**
 - **Delta**
 - **Ratio (Reliability)**
 - **Component Analysis - Identifies Where Remedial Fixes Can be “De-coupled”**
- **Considerations:**
 - **Engineer Ratings**
 - **Relative Uncertainty of Data**
 - **Construction Costs**
 - **Construction Durations**

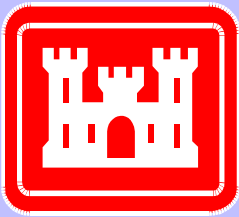


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Relative Risks Data Reduction



- **Baseline Risks**
- **Total Relative Risks:**
calculated from
SPRA
- **Delta Risks:**
= Total - Baseline Risks
“risk reduction
effectiveness”
- **Reliability Index:**
= Total/Baseline Risks
“unreliability”



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Component Risks (Example)

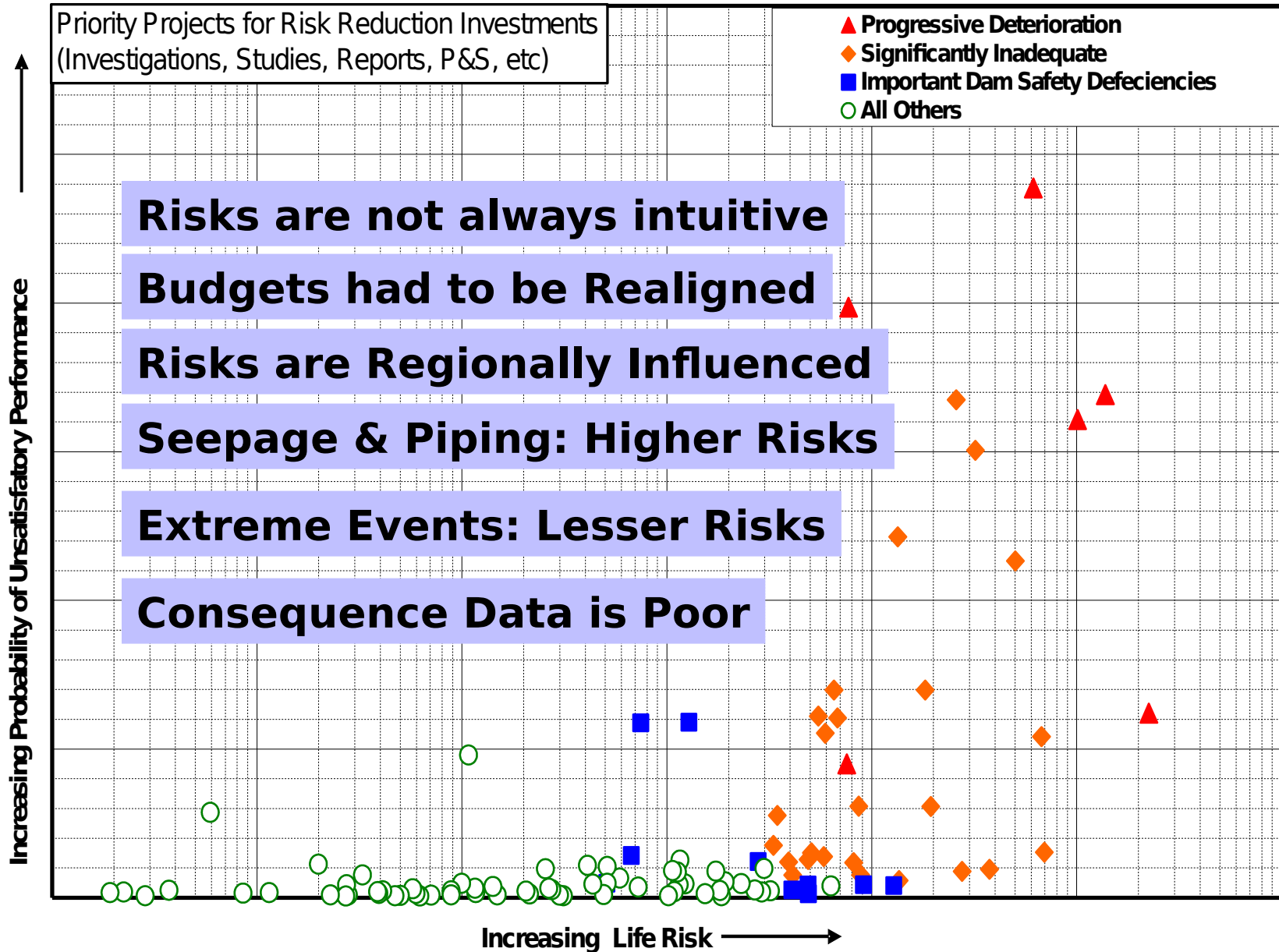
2005/8/23 / Round_1

COMPONENT RISK > 0.01999 are shown in yellow

Dam ID	Gates	Seepage and Piping	Erodibility	Stability	Seismic OBE	Seismic MDE
Dam Names Omitted for Security Purposes	0.04770	21.20000	0.71000	0.2140 0	0.10700	0.07270
	0.08660	13.50000	0.01080	0.1180 0	0.00211	0.00008
	0.00043	9.43000	0.05250	0.1030 0	0.05740	0.00289
	0.00516	3.44000	0.37300	2.7700 0	2.39000	0.12100
	0.00556	5.86000	0.03460	0.2440 0	0.00067	0.00003
	0.00032	4.54000	0.11200	0.0023 4	0.00049	0.00002
	0.00022	3.19000	0.00764	0.0093 2	0.00000	0.00000
	0.00103	2.57000	0.00082	0.0032 2	0.00025	0.00001
	0.01700	0.02500	0.02560	1.6200 0	0.00000	0.00000
	0.00020	1.62000	0.00419	0.0028 3	0.00027	0.00001
	0.00082	1.33000	0.00490	0.0122 0	0.00000	0.00000
	0.00740	0.66400	0.17700	0.1060 0	0.03520	0.00287
PA00109 / YOUGHIOGHENY DAM	0.03150	0.07350	0.49300	0.2750 0	0.02880	0.00130
PA00105 / KINZUA DAM						

USACE DAM SAFETY PROGRAM - SPRA RESULTS

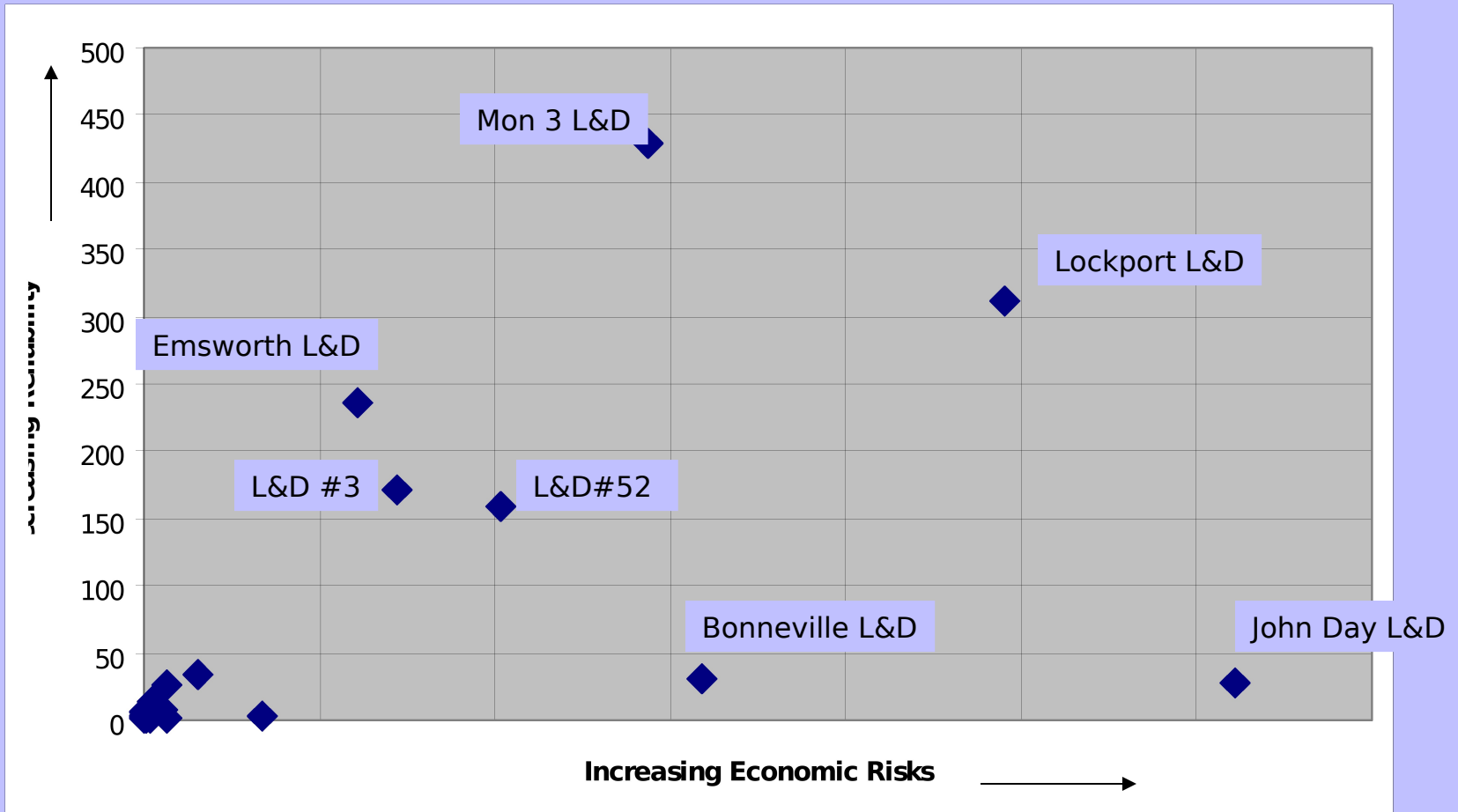
(FY05 and FY06)

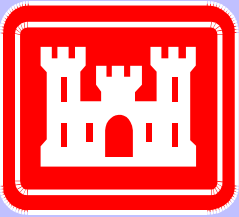




SPRA Economic Risks: Navigation

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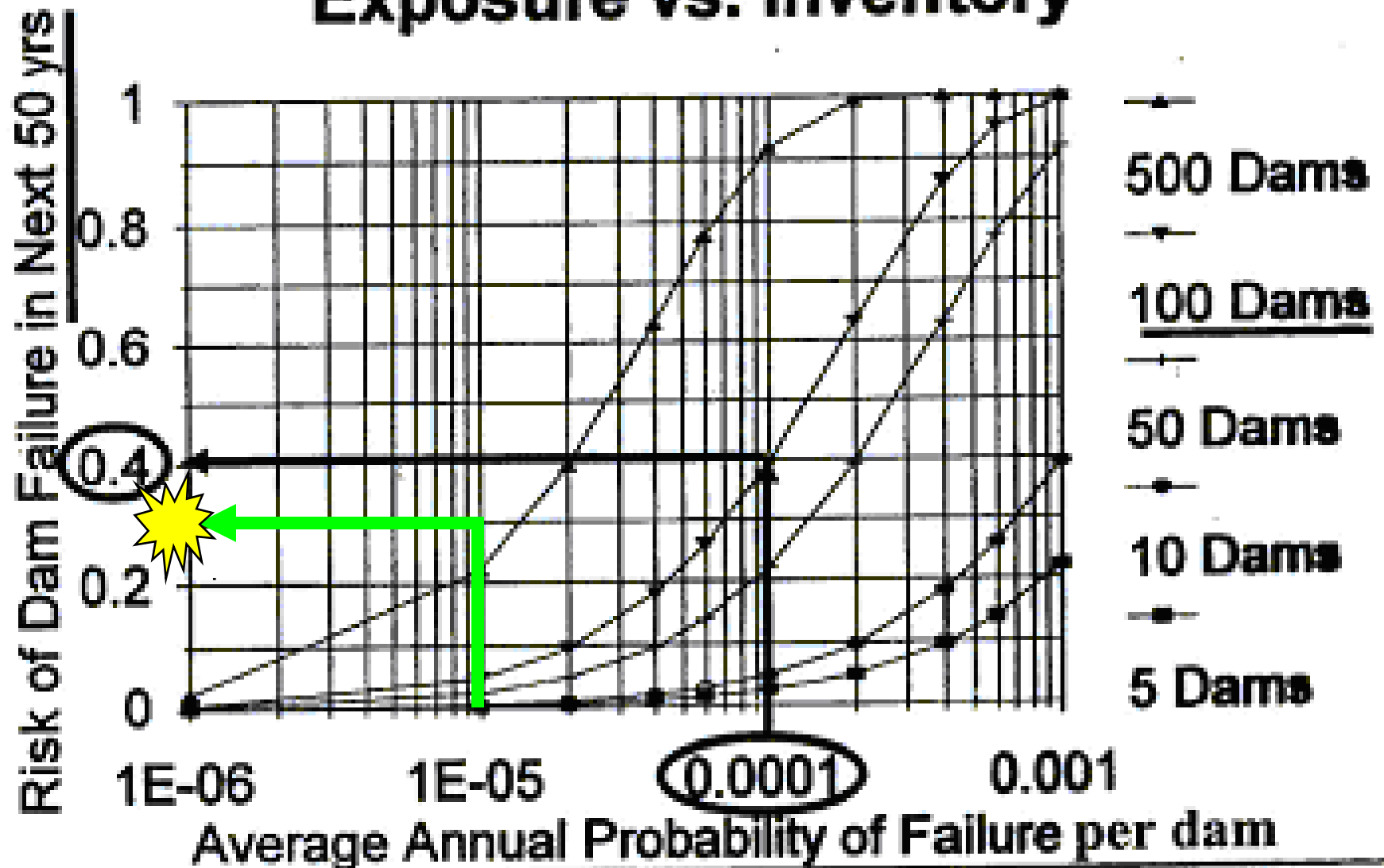
U.S. Army Corps
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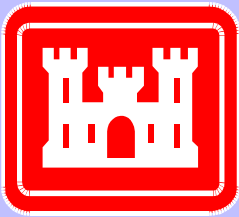
Challenges

- **Staffing:**
 - Additional Cadres to Accomplish Initial Assessments
 - Long Term Skill Sets
- **Integrated Management:**
 - Centralized Resourcing & Management
 - Regional, Permanent Cadres
- **Re-Engineering the Dam Safety Program**
 - Risk Based Routine Activities
- **Coordination with Other Corporate Management Initiatives**

Portfolio Probability of Failure

Exposure vs. Inventory





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